



Does an increase in plant diversity enhance agroecosystem services? Case study in rainfed rice based cropping systems in Madagascar

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1 – Introduction

In the Mid-West of Madagascar, lowland flooded rice is the traditional rice cropping system, but recently upland rainfed rice has been expanded due to lowland saturation. Yet, rice yields remain low due to very poor soil fertility, high pest, weed and disease pressure and little access to external inputs. Farmers cannot afford price for pesticides or weeder or other tools (Razafimahatratra et al., 2017). They usually use a traditional spade called “angady” to plough the fields, prepare sowing making a hole for rice seeds, and to weed. In these conditions, where cultural practices are time consuming and farmers cannot always pay for external labour, increasing managed biodiversity within crop rotations may help improving yield while providing agroecosystem services such as pest and weed regulation and soil restoration (Ratnadass et al., 2012). This study aims at analysing the effect of increased plant diversity in crop rotation on yields, pests and weeds regulation, soil biological activity and fertility in rainfed rice based cropping systems.

2 – Materials and methods

A field experiment was carried out near the Ivory village (19°33'18.90'' lat. S, 46°24'53.83'' long. E, 930 m.a.s.l.) during three cropping seasons (2015/2016; 2016/2017; 2017/2018). Three rotations, namely (i) Rice after Groundnut (RG), (ii) Rice after Sorghum-*Vigna unguiculata* intercropping (RSV) and (iii) Rice after *Mucuna cochinchinensis*-*Crotalaria spectabilis* intercropping (RMC) were compared to rainfed rice monoculture (RR) in a factorial randomized block design with four replications. Each crop or crop mixture of the rotation was present each year of the experiment and was grown on 45.9 m² plots. Soil nitrogen was measured at rice sowing on RR monoculture and RMC rotations. It was approximated for RG and RSV rotations based on the biomass



produced the previous year and its N content. Weed and rice biomass were measured at each weeding date, and rice biomass was also measured at flowering and harvest. White grubs were counted at each of these dates (both weedings, flowering and harvest) and separated by families. All these measurements and counting were done simultaneously on the same subplots of 0.54 m² during the 2nd and 3rd cropping seasons of the experiment. Soil nematodes were extracted from a composite soil sample made before flowering the 1st and 3rd year, then counted considering the different existing families. Here we focus on plant-parasitic nematodes. Macrofauna abundance was evaluated from soil monoliths (20 cm × 20 cm × 30 cm) just before flowering each year of the experiment. Rice yields were measured at harvest on 4.6 m² plot. Grain samples were dried during 3 days at 60°C to calculate yield on a dry matter basis. The different crops in rotation with rice were also harvested to quantify their aerial biomass, and yield when relevant (i.e. for groundnut, sorghum and cowpea).

Rotations were then assessed based on a simple profitability analysis and four ecosystem services represented by six indicators: (i) yield for production, (ii) weed biomass, (iii) white grubs and (iv) plant-parasitic nematodes abundance for pest regulation (v) soil nitrogen content for soil fertility, and (vi) macrofauna abundance for biological activity. Profitability analysis was made considering current prices for rice, groundnut and cowpea. Surplus of soil nitrogen provided by crop from rotations compared to monoculture was converted in money based on the current price of fertilizer. Weeding cost were evaluated based on the labour needed to weed of all fields and the weed biomass harvested on the different crop rotations. Finally, we calculated a gross margin for each crop rotation.

3 – Results – Discussion

White grubs pressure remained low whatever the treatment during all the experiment (from 0 to 4 individuals per field on average, data not shown). After the first two years of crop rotation, rice production decreased in RR monoculture (-0.6 t.ha⁻¹) while weed and plant-parasitic nematodes pressure increased (+70 and 40% respectively compared to the 1st year, Fig.1). On the contrary, RMC rotation had positive impacts on the different ecosystem services indicators. Performances of RSV and RG rotations were intermediate considering yield, soil nitrogen surplus (ca. 10 kg.ha⁻¹ estimated) and biological activity or pest regulation. Nevertheless, RR and RG were the most profitable options after one cycle of rotation mainly due to the value of rice and groundnut production despite a relatively high weed pressure, particularly in RG (Fig 1).

During the second cycle, RG and RMC turned out to be the most profitable options. RMC appeared to be the most interesting one because of the huge increase of rice yield (+ 40% the third cropping seasons, 3.8 t ha⁻¹) combined with a significant decrease in weed pressure and consequently in labour cost for weeding. Higher yields could result from, on one hand, a better soil fertility (+40 kg.ha⁻¹ soil N at sowing); and on another hand a reduced weed pressure due to the high production of biomass during the growing season of the crop mixture (Fig.1) that gave rice a competitive advantage to grow. RR obtained low margin as RSV due to lower yield (-40%) and higher weeding cost. RSV was not so interesting given the low yield of cowpea and the fact that sorghum is not yet a crop used by farmers in Madagascar, so we could not give it a specific profitability value.



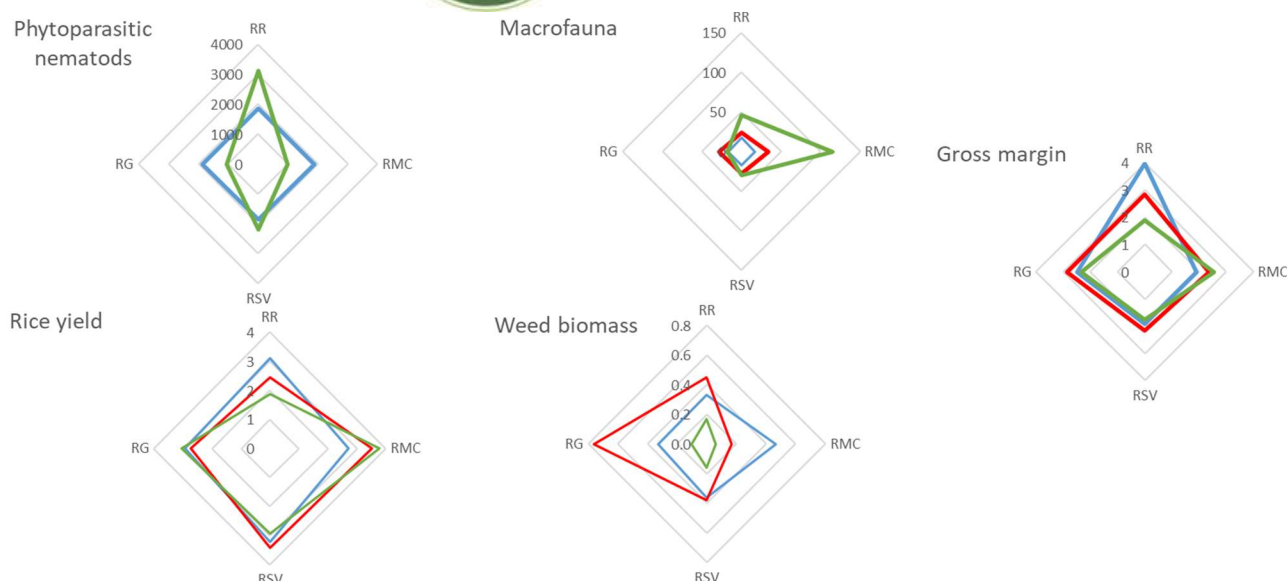


Figure 1. Multicriteria assessment and profitability analysis of the three crop rotations compared to the rice monoculture for the three cropping seasons: example of four indicators (plant-parasitic nematode and macrofauna abundance, rice yield and weed biomass).

RR = Rice // Rice; RG = Rice // Groundnut; RSV = Rice / Sorghum + cowpea; RMC = Rice // Mucuna + Crotalaria

Blue, red and green lines correspond to the first cropping season (2015/2016), the second one (2016/2017) and the third one (2017/2018) respectively. Plant-parasitic nematodes and macrofauna abundance are expressed in number of individual observed per field, rice yield and weed biomass in ton per ha and gross margin in euros.

4 – Conclusions

Even in only three years, plant diversity quickly affected agronomic and economic performances of cropping systems. Alternative rotations based on greater plant diversity are promising, but their actual uptake by farmers will depend on their promotion by adequate public policies or improvement with cash service crops (e.g., a groundnut cultivar which is able to cover soil and compete weeds and that is appreciated by consumers) as farmers cannot afford to grow fields that do not bring in cash or staple food.

References

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